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ABSTRACT

The Preparing Elementary Teachers to Teach Mathematics Project is a cooperative university/school effort to improve the teaching of mathematics by elementary teachers. Although the primary focus of the project is the improvement of the university training of preservice teachers (PSTs) in mathematics, there are two important collaborative aspects to this project. The first is the development of a close working relationship with a school district to jointly sponsor and supervise early field experiences for all PSTs. The second is the establishment of support mechanisms to help practicing teachers in the school district in broadening their views of the nature of mathematics and in utilizing innovative teaching techniques for improving mathematical thinking skills and use of problem-solving strategies. Thus, local teachers should eventually be able to serve as role models in the teaching of mathematics using a problem-solving approach. (Author/JD)

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Preparing Elementary Teachers to Teach Mathematics with a Problem-Solving Approach: A University/School Collaborative Effort

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The project described in this paper is a product of the Mathematics Education Development Center of the Indiana University School of Education. Dr. John F. LeBlanc and Dr. Frank K. Lester, Jr. are the co-principal investigators. The project is supported by National Science Foundation Grant #NSF TEI 8751478, and the teacher workshops mentioned in the paper are supported by the State of Indiana Department of Education. Any opinions, conclusions, or recommendations expressed here are those of the author and do not necessarily reflect the views of either the National Science Foundation or the Indiana Department of Education.

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Preparing Elementary Teachers to Teach Mathematics with a Problem-Solving Approach: A University/School Collaborative Effort

The *Preparing Elementary Teachers to Teach Mathematics Project (PETTM)* is a cooperative university/school effort to improve the teaching of mathematics by elementary teachers. Although the primary focus of the project is the improvement of the university training of preservice teachers (PSTs) in mathematics, there are two important collaborative aspects to this effort.

The first is the development of a close working relationship with a school district to jointly sponsor and supervise early field experiences for all PSTs. The second is the establishment of support mechanisms to help practicing teachers in the school district in broadening their views of the nature of mathematics and in utilizing innovative teaching techniques for improving mathematical thinking skills and use of problem-solving strategies. Thus, local teachers should eventually be able to serve as role models in the teaching of mathematics using a problem-solving approach.

The three-year project is funded by the National Science Foundation, with additional funding for related activities from the Indiana Department of Education. The project utilizes the joint efforts of staff from the Indiana University Mathematics Education Development Center and the Indiana University Mathematics Department along with the efforts of teachers from a local school, Dyer Elementary of the Monroe County Community School Corporation.

Background and Rationale

A number of recent national reports have called for the improvement of education at all levels. Three reports which have attracted national attention are the NCATE Redesign (Gollnick & Kunkel, 1986), the Holmes Group report (1986), and the report of the Carnegie Task Force (1986). Based on the assumption that the quality of education is directly related to the quality of the teachers, these reports propose dramatic changes in the practices used in recruiting, preparing, and certifying elementary school teachers. Both the Holmes Group and the Carnegie Task Force reports call for the elimination of undergraduate programs. All of the reports propose broader and deeper backgrounds in liberal arts. The reports also call for closer ties and working relationships between the teacher preparation institution and the school districts.

An elementary education Task Force at Indiana University studied the reports and, while seeing merit in many of their recommendations, declined to join the Holmes group. Although educators at Indiana University certainly agrees with the need for graduate work in education, they also feel that such study is more profitable after some teaching experience has been acquired. Further, the Task Force believes that it is quite possible to train elementary school teachers in a well designed four-year program (cf., Mehlinger, 1986). Thus, Indiana University is in the process of designing a new four-year elementary education program, a program which will incorporate many of the recommendations common to the reports mentioned above.

Faculty in Mathematics Education and in Mathematics at Indiana University saw the revision of the teacher education program as a unique opportunity to improve the mathematics preparation of elementary teachers. In particular, two elements of Indiana University's proposed new four-year program have a direct relationship to the work of the *Preparing Elementary Teachers to Teach Mathematics Project* (*PETTM*). These two elements are:

1. each elementary education major must complete an 18-24 semester credit hour concentration in an approved area (one of those areas being mathematics); and
2. each prospective elementary education major must take part in a three semester sequence of concentrated early field experiences working in a school prior to student teaching.

Thus, the *PETTM* Project, a project of the Indiana University Mathematics Education Development Center (MEDC) is aimed at:

1) better preparing all elementary school teachers through a problem-

solving focus in newly developed mathematics courses at the university;

2) developing a program of concentration in mathematics consisting of some existing courses and some newly developed courses and experiences to prepare students who wish to make mathematics their field of concentration;
3) developing a close working relationship with the local school district to jointly plan for intensive early field experiences for all prospective teachers;
4) assisting practicing teachers in the school district to develop as models in teaching mathematics using a problem-solving approach.

Project Description

The *Preparing Elementary Teachers to Teach Mathematics Project* has a number of components, all of which are designed to contribute to improving mathematics instruction in elementary schools. The following project components will be described in turn: the Content Component, the Methods Component, the School Component, the Dissemination Component, and the Research and Evaluation Component.

The Content Component

This component involves revision of the university mathematics courses required of PSTs in a fashion that can be exported to other teacher training institutions. Currently, at Indiana University all prospective elementary teachers take three mathematics courses that are not available for credit to students in any other fields. Almost all other students at Indiana University enroll in regular mathematics courses in which they mingle with students with

a large variety of majors. One part of our proposal is to begin to train prospective elementary teachers using two courses: a regular mathematics course (finite mathematics) , and a new mathematics course for education majors. Both of these courses are being developed so that problem solving is a central focus; in other words, efforts are being made to teach university-level mathematics with the same problem-solving approach that the Project would like to see teachers use when they work with children.

The Methods Component

Two major efforts have been identified for the methods component of the Project: to develop well-structured field experiences for both the existing mathematics methods course and a proposed new problem-solving methods course, and to develop and institutionalize the new problem-solving methods course (to be required, along with additional mathematics courses, of those students who elect mathematics as their area of concentration).

Field Experiences. Associated with a three-credit mathematics methods class currently required of all PSTs is an early field experience in which students work with small groups of pupils in one of the local schools. In addition to increasing the number of early field experience visits associated with the mathematics methods course, the Project will, for the next three years, consolidate all of these early field experience assignments into a single school within the local public school district. The aim is to make this school, Dyer Elementary, a "model" site for the teaching of mathematics. Primary efforts to improve the field experiences include development of a field experience coordinator's notebook (to describe the organization and implementation of the field experiences) and a series of model lesson plans with accompanying

videotapes of these model lessons being taught to actual children (for use in workshops preparing students for their work in the field).

Problem-Solving Methods Course. The new course, entitled "The Nature of Mathematical Problem Solving," will be open to all PSTs, but required of those who choose mathematics as their area of concentration. The course will be designed to increase prospective teachers' familiarity with issues related to the teaching and learning of problem solving as well as to increase their own ability to solve mathematical problems. Plans also call for development of units related to the diagnosis and remediation of pupil difficulties, a professional problem-solving skill. This course will also include a field experience (at our project-related school, Dyer Elementary) which will focus on instruction in problem solving as well as on experience with diagnosis and remediation of pupil errors in mathematics.

The School Component

An important part of the training of PSTs is experience with classroom teachers and their students. The purpose of the school component of the Project is to get Indiana University faculty working together with faculty from an elementary school (Dyer) to provide the best possible environment for field experiences for IU students. Dyer has been a site for IU mathematics early field experiences for a number of years. In these experiences, IU sophomores and juniors enrolled in mathematics methods classes were assigned several lessons to teach to a small group of Dyer children. The lessons IU students were assigned to teach were separate from rather than integrated into the regular Dyer mathematics curriculum. The reason for this was that the lessons involved manipulative and problem-solving activities which few public school teachers

were able to direct. By working closely with Dyer faculty throughout the duration of this Project, we hope to show that a typical elementary school can be made into a place where preservice teachers can see mathematics being taught from a problem-solving perspective. As part of this objective, we will develop sample lessons which to help both preservice and classroom teachers teach with a problem-solving focus.

Dyer Elementary School. Dyer Elementary is the second largest elementary school in the county school system, with about 500 pupils in grades K-6. The children at Dyer represent a socio-economic mix: although some are children of professionals or of university faculty, a majority come from families with much lower income levels (e.g., half of the Dyer children qualify for free or reduced-price lunches). While some Dyer teachers have worked with IU faculty members in previous years (because Dyer has been a site for university field experiences), Dyer was chosen as a site for Project work because the faculty expressed an interest in joining the Project, and because it was evident that the Dyer teachers might profit from a program designed to broaden their views of mathematics and their notions of how problem solving can be integrated into the elementary mathematics curriculum. Many of the teachers at Dyer are career professionals with ten or more years of experience. There are, however, several first and second year teachers as part of the staff. Working at Dyer School is a challenge since Dyer is, in fact, a very typical school with a very typical faculty. If we are successful in getting Dyer teachers to include mathematical thinking and problem solving in their daily mathematics lessons, we will feel confident that the techniques and products developed at Dyer can be successfully disseminated to other sites.

Inservice Training at Dyer Elementary. During the spring semester of 1988, a number of visits were made by Project staff to Dyer classrooms to get a better feel for how mathematics was being taught to Dyer students and to build an atmosphere of mutual trust and respect between IU and Dyer. Inservice training of the Dyer staff began in earnest in August, 1988 with a full day workshop on problem-solving, and is continuing throughout the 1988-89 and 1989-90 school years.

A full-time mathematics resource teacher hired by the Project began work at Dyer in May, 1988, and is now spending much of her time at Dyer working with individual teachers. She teaches classes on a demonstration basis, provides samples of model instructional materials designed to enhance pupils' acquisition of problem-solving and mathematical skills, assists with coordination of inservice workshops, works with individual and small groups of teachers in developing strategies to implement goals set up in workshops, helps teachers select and construct materials and activities, and generally serves as a liason between the teachers and other Project staff. The resource teacher also serves as a school/university liaison for the early field experiences of the mathematics methods students .

A math office has been set up at Dyer and equipped with a wide variety of manipulatives and supplemental mathematics materials. The office also contains an extensive library of inquiry-oriented supplemental books which the Dyer staff are using (in cooperation with the resource teacher) to generate problem-solving oriented lesson plans.

Indiana Department of Education Inservice Workshops. In spring, 1988, as Project staff were planning inservice work with Dyer teachers for the 1988-89

school year, it was suggested that these efforts could be significantly strengthened if, as a supplement, Project staff could call on experts from around the country to serve as keynote speakers at a series of workshops to introduce the Dyer teachers to important contemporary topics in planning mathematics curricula in the elementary school. Thus, the IU Mathematics Education Development Center (MEDC) applied to the Indiana Department of Education for monies for a series of six workshops to take place throughout the 1988-89 school year. Although the workshops, which last about four hours each, are open to small teams of teachers from elementary schools throughout the local area, all Dyer teachers attend. The primary speaker at each workshop is a mathematics educator with special expertise or experience with a topic critical to the teaching of mathematics at the elementary level. For the Dyer faculty, these workshops are a supplement to an ongoing series of small group and individual meetings with the resource teacher and with other Project staff throughout the school year.

Curriculum Development by Teachers. As a result of the resource teacher's encouraging presence, the inservice workshop(s), the availability of materials, or--most likely--as a result of these combined factors, teachers at Dyer seem to be changing. One can observe problem-solving lessons taking place and an enthusiasm for teaching mathematics that was not observed last spring. However, a need has been identified by the teachers, and the Project hopes to be able to respond to it. Teachers need a grade-level notebook of problems and resources for teaching problem solving. At the present time there is no compilation of problem-solving resources that might be useful to a teacher trying to incorporate a problem-solving focus into his or her mathematics instruction. In our original plans, we had hoped that the Dyer teachers could produce

problems appropriate for their grade levels. It is clear that during the academic year, time does not permit teachers to engage in such an activity.

To produce grade-level problem-solving resource notebooks for teachers, we have proposed identifying six teachers, one each at grades 1 to 6, to work during the summer for a period of four consecutive weeks to produce the needed resource notebooks. Time will be spent initially in an orientation to the kinds of problem-solving materials which will best aid the desired instruction. Project personnel will have gathered an extensive library of resources with which the teachers might work. Pairs of teachers (grades 1-2, 3-4, 5-6) will be assigned the task of identifying problems and resources appropriate for their grade levels and the kinds of pupils they might instruct. The writing session will be directed by the resource teacher and monitored by one of the senior Project staff. The resulting notebook will not only be used by Dyer teachers, but also made available (at cost) to other teachers since, as a result of the Project's presence (and the Department of Education-sponsored workshops), teachers from a number of other local schools have become interested in problem-solving instruction.

IU Mathematics Field Experiences at Dyer. In addition to work with Dyer faculty, the school component of the Project is collaborating with the methods component on revision of the university's mathematics early field experience. Work on the field experience helps to achieve goals of both Project components simultaneously. Plans call for more teaching time for IU students, as well as improved workshops to help these prospective teachers prepare lessons appropriate for Dyer children. These lessons, now being developed at IU, will eventually be developed cooperatively with Dyer teachers and may be made available for distribution. These changes should help make IU students feel

more like a part of the Dyer community and make Dyer faculty feel more involved in the training of prospective teachers. It should be noted that we view the entire school component as a cooperative venture between IU and Dyer, with responsibility for success falling on both groups.

During the spring semester of the 1988-89 school year, a Mathematics Fair with the theme "Problem Solving in Our Lives" will be held at Dyer . While plans for this fair are just now being developed, it has already been agreed that the spring semester field experiences of the university students will in large part be focused on helping classroom teachers and children to develop, solve and display appropriate problems for the Fair.

The Dissemination Component

The fourth component of the Project involves disseminating to a wider audience the programs, materials, and ideas that the Project generates. The MEDC's sponsorship of the Department of Education workshops (mentioned above) for elementary teachers is one example of such dissemination -- an effort to share our problem-solving perspective (and similar perspectives from experts from around the country) with elementary teachers from throughout our local area, not just with teachers from our adopted school, Dyer Elementary.

In a dissemination effort designed to reach teacher educators, the MEDC has recently applied for a grant from the Indiana Higher Education Commission for funding to organize and carry out a conference (in spring, 1989) for educators responsible for the mathematics inservice and/or preservice training of elementary teachers in Indiana. The proposed conference has the following goals: (1) identifying and discussing academic and social issues related to contemporary teacher training programs; (2) discussing innovative teacher

training programs in mathematics (including, among several, our own *PETTM* Project); (3) creating a network among those responsible for the mathematics training of elementary teachers in Indiana so that future dissemination of ideas will be easier to accomplish; and (4) (to the extent that agreement among the participants is possible) creating and publishing a list of guidelines/ standards for the preservice/inservice mathematics training of elementary teachers in Indiana.

It is also anticipated that many of the curricular materials developed under auspices of the Project (both for training prospective elementary teachers and for teaching children) will eventually be published, and thus made accessible to a much wider audience.

The Research and Evaluation Component

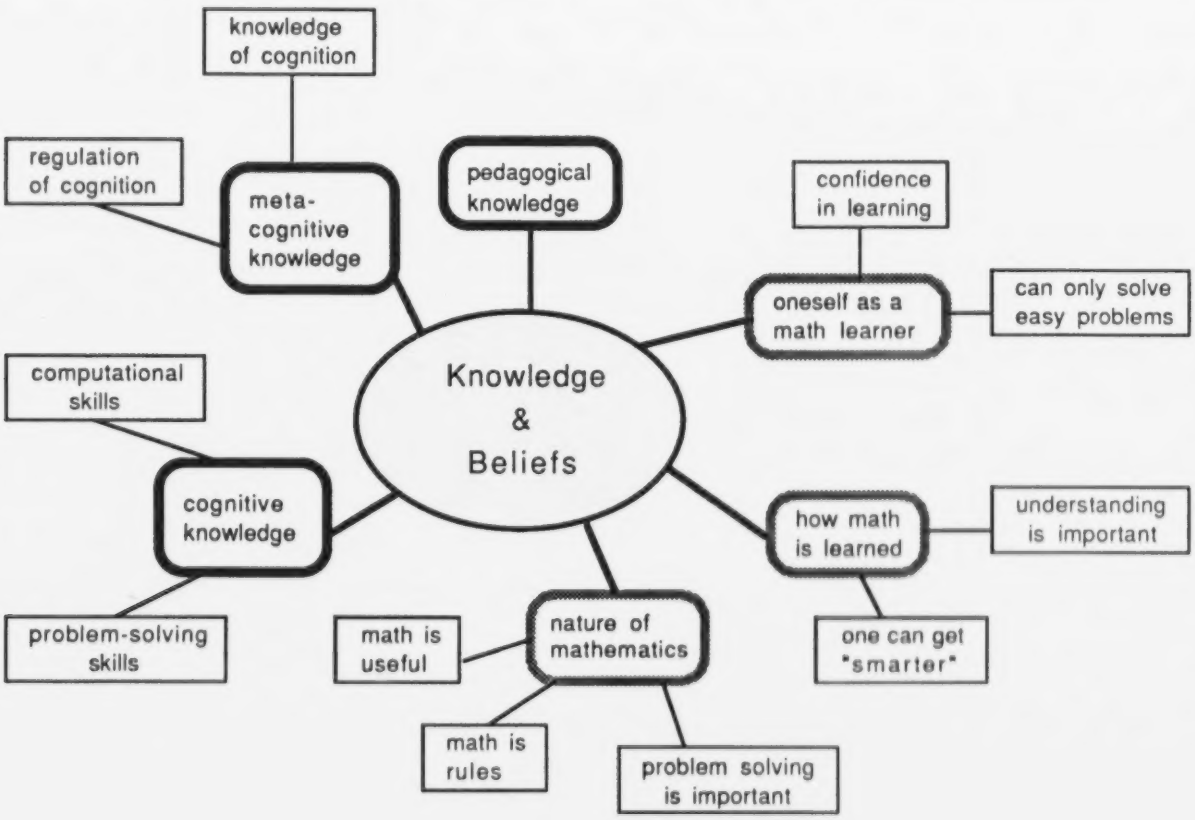
The main purpose of the Research and Evaluation Component is to determine the effectiveness of each of the other components of the project. A long range goal of the entire project is to provide an improved model for training elementary teachers. By knowing which innovations have been effective, project staff will be able to provide a tested plan for training elementary teachers to teach mathematics.

It is perhaps obvious that a number of factors influence how teachers teach. Some of these factors, such as the State of Indiana requirement that teachers spend at least 225 minutes per week teaching mathematics, are beyond the control of individual teachers (at least in the short term). These factors can be regarded as "uncontrollable." However, a number of factors are within the control of teachers. For example, a teacher's knowledge of and beliefs about mathematics are susceptible to change and therefore are considered as being under the control

of teachers. Such factors, which we refer to as "teacher knowledge and beliefs," are those that we hope to influence. Consequently, it is these factors on which research on the project will focus.

To a large extent, knowledge and beliefs are dependent upon the training a teacher receives. Figure 1 depicts several of the types of knowledge and beliefs that we have deemed relevant to the nature of our project. Although we are aware

Figure 1: Teacher Knowledge and Beliefs Affecting Teacher Decisions



that the distinction between what is knowledge and what is a belief is not always clear, it is our position that beliefs are subjective knowledge (i.e., not necessarily objectively true). Furthermore, knowledge affects an individual's beliefs and visa

versa. With this in mind, in Figure 1 teachers' knowledge has been divided into three subcategories. The first is cognitive knowledge such as computational and problem-solving abilities. The second, metacognitive knowledge, deals with an individual's ability to monitor his or her own thinking, particularly with respect to mathematical problem solving and with respect to teaching problem solving. The third category is pedagogical knowledge, the focus of the methods component of the project.

On the beliefs side of the diagram, it can be seen that beliefs have been categorized with respect to oneself as a learner of mathematics, how mathematics is learned, and the nature of mathematics. Beliefs about oneself are critical, since a student's belief that he or she cannot learn mathematics results in low motivation and interest on the part of the student and a feeling of futility on that student's teacher. Beliefs about how mathematics is learned are also critical. For example, a teacher who believes that teaching students to "get the right answer" is more important than teaching them to understand why a solution procedure works will probably not be very effective when it comes to teaching problem solving. The third category of beliefs, those about the nature of mathematics, are important as they again influence the way teachers teach. Teachers who believe that mathematicians spend their time "cranking out" tedious computations are not likely to think they should teach students to solve non-routine problems.

The research and evaluation component of the project will attempt to determine how effective the project has been in influencing each of these knowledge/belief factors. Measurement of the various factors will usually be done with multiple indicators. Major instrument development to date has focused on

construction of belief scales for many of the belief variables shown in Figure 1.

Other methods of collecting data on knowledge/belief variables are also being used as part of this study. Achievement data from standardized tests are being collected from students at Dyer Elementary School (see below). Data on math course grades, math SAT scores, and high school math backgrounds are being used as mathematics achievement indicators for preservice teachers. At Dyer, IU staff have been writing notes after each observation as part of an effort to include qualitative data as part of the research and evaluation effort.

As noted, the research and evaluation effort include a several target populations. The primary purpose of the project is to improve teacher training, and thus preservice teachers are being studied in depth. The belief scales noted above were administered to the 140 students enrolled in the elementary mathematics methods course in the fall of 1988. The scales were administered during the first week of class for baseline data and used again at the end of the semester as a post-treatment measure. The same scales were used in September, 1988 with 300 freshmen in their first semester at IU. Contrasting the beliefs of the juniors in the mathematics methods classes with those of the freshman sample will give some indication of how two years of college (years which included two or more mathematics classes) have influenced beliefs. If beliefs appear to have been influenced in a negative direction by college experiences (or if beliefs of the juniors are uniformly poor), we will know that changes in mathematics class format must be made, taking into consideration how the structure and content of those classes may influence beliefs. Because background achievement data are being collected on both freshman and junior populations, it should also be possible to determine correlational relationships between achievement and beliefs.

A second population of interest in this project is the students at Dyer elementary school (see the Inservice Component). It is anticipated that improved instruction by the Dyer staff and the increased exposure of Dyer students to the field experience will result in gains in mathematics achievement beyond what would normally be expected. As part of State of Indiana and local school district testing programs, achievement test data were collected on all students at Dyer in the spring of 1988. With the three years of data that we will have on Dyer students, it will be possible to determine the impact of the project on the mathematical growth of the children who have been indirectly affected.

In summary, the research and evaluation component is a multifaceted effort. It is focused on determining the extent to which the project's model of teacher training can influence the knowledge and beliefs of individuals completing the program and on using data on Dyer students and teachers to determine the effect of the project on these participants.

Conclusion

The *Preparing Elementary Teachers to Teach Mathematics Project* is multifaceted, aiming to improve the teaching of mathematics in the elementary schools by encouraging teachers to use a problem-solving approach. Although the major focus of the Project is the design and implementation of a new program of studies for prospective elementary teachers at Indiana University, an essential element in this endeavor has been establishment of Dyer Elementary School as a site for all Project-related field experiences, and the provision of frequent and ongoing inservice work for the Dyer faculty so that Dyer can serve as a model site for the teaching of mathematics with a problem-solving approach.

Faculty from Indiana University are enthusiastic about this collaborative

approach, and teachers from Dyer are proud to be a faculty involved in the improvement of teacher training. Progress that has been made thus far indicates that practicing teachers can and should be involved in the training of new teachers and that the chances for success of this model for teaching training are good.

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